

COMPARTMENT SYNDROME (CS) AND THE ROLE OF FASCIOTOMY IN EXTREMITY WAR WOUNDS

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<input type="checkbox"/> Minor Changes (or)	<input type="checkbox"/> <i>Changes are substantial and require a thorough reading of this CPG (or)</i>		
<input type="checkbox"/> Significant Changes:			

1. Goal. Provide an overview of CS and present a standardized approach to guide providers in the evaluation and treatment of patients with extremity war wounds, including the role of prophylactic and therapeutic fasciotomy.

2. Background. Compartment syndrome (CS) is a common, controversial, and disabling problem in the current war. Recent research indicates proper detection of compartment syndrome is lifesaving; and lethal if late.¹ The operational definition of compartment syndrome is a clinical syndrome wherein high pressure within a myofascial space reduces perfusion and decreases tissue viability. Therapeutic fasciotomy is indicated for established compartment syndrome, and prophylactic fasciotomy is indicated for risk of compartment syndrome.²⁻⁴ Fasciotomy during lag phase between injury and syndrome onset is prophylactic. Early detection is challenging, so prophylactic fasciotomy is routine when compartment syndrome is likely; but the circumstances for prophylactic fasciotomy are unclear. Injury, treatment, and casualty variables affect risk (Tables 1 and 2).¹⁻⁷ Variable importance and their time lags differ widely, but the main factors are limb injury severity (particularly vessel injuries), and overall casualty injury severity (particularly shock) with a lesser factor being over-resuscitation (particularly >5 liters of crystalloid). Some factors are interrelated, e.g. in rats functional loss resulting from tourniquet use is worsened by additional hemorrhage in fast-twitch but not slow twitch muscles. Surveys indicate surgeons with more education and experience are willing to perform fasciotomy more often, and the fasciotomy rate has increased five-fold in the current war. Initially, the rate was too low, but the optimal rate is unknown. Other variables may affect limb ischemia-reperfusion with swelling. In and of itself, injury swelling maximizes in 1 to 2 days, additional swelling from post-injury ischemia-reperfusion (e.g., revascularization, shock, tourniquet use) appears to delay maximal limb swelling further; perhaps to 2 to 3 days post injury. Problems with compartment syndrome include morbidity and mortality (Table 3). High altitude (including normal AE aircraft cabin pressure), in and of itself, is not a contributor to compartment syndrome. Once the decision has been made to perform a prophylactic or therapeutic fasciotomy, a complete fasciotomy must be performed. There is evidence to support complete compartment release by full-length skin and fascial incisions is superior to limited fasciotomy.

3. Evaluation and Treatment.

- a. The signs and symptoms of CS are the classic 5 P's which include: pain on passive stretch of muscle often out of proportion to that of the injury as expected by the provider; palpably tense muscle compartments; paralysis; paresthesias or sensory deficit; pulslessness.² Pain is sensitive and early given a cooperative casualty, but it is not

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specific. Palpably tense muscle is specific but not sensitive, and usually there is some swelling; rigor is differentiated by stiffness. Paralysis and paresthesias are generally late and least helpful acutely. Pulselessness is seen virtually never in civilian compartment syndrome, but occurs rarely in war, sometimes within minutes of an arterial injury or an expanding hematoma.

- b. The most common compartment syndrome is in the anterior leg.¹⁻² About 45% of all compartment syndromes are caused by tibia fracture, and Volkmann's contracture occurs in 1% to 10% of cases of CS. Open fractures, even with traumatic fasciotomy, have higher CS rates than closed fractures because they are more severe, with more swelling and more often injured arteries. The most commonly missed compartment syndromes are the anterior and deep posterior compartments of the leg. The most commonly incompletely released compartments are also in the leg.¹
- c. Passive stretch pain (e.g., ankle dorsiflexion), palpation of muscles for tenseness, and pulse quality. Pressure monitoring by manometer does not diagnose reliably CS in theater, so the diagnosis remains a clinical, not a laboratory, diagnosis. Since there is currently no sensitive or specific technique for establishing the diagnosis of compartment syndrome, a fasciotomy should be considered in a patient with significant mechanism of injury and clinical findings suspicious for compartment syndrome.
- d. When monitoring patients for the development of CS, serial clinical examinations are repeated hourly when risk is high and less frequent when low. Provider experience and training improve detection. Documentation is important for later providers and performance improvement. The methods of manometric monitoring of compartments and the clinically significant thresholds to identify compartment syndrome are, at present, not known. A new manometer drains fluid.
- e. In one study, burns sustained in combat have been associated with an increased fasciotomy rate.¹ **In the absence of crush injury, fracture, multiple trauma, over-resuscitation, electrical injury or similar indications, prophylactic fasciotomies on burned extremities may increase morbidity and mortality and are not indicated.** (For additional information on escharotomy and fasciotomy in the management of patients with extremity burns, see "Burn Care" JTTS CENTCOM CPG, 21 Nov 08).
- f. When established limb compartment syndromes prolonged, complications (mortality, infection) are frequent according to the best evidence available⁶. These casualties may meet indications for resuscitation, urine alkalization, mannitol use, and intensive support. Such conservative care has led to better outcomes than fasciotomy in casualties with closed injuries with mechanically crushed muscle (see Figure 1 and Reis & Better, 2005). So for compartment syndromes that last more than 12 hours (warm ischemia) and the muscle appears to be dead, there may be better outcomes with conservative care than fasciotomy.

4. **Author:** COL John Kragh is the primary author of this CPG.

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5. References.

- ¹ Ritenour AE, Dorlac WC, Fang R, et al. Complications after fasciotomy revision and delayed compartment release in combat patients. *J Trauma*. 2008;64(2 Suppl):S153-61; discussion S161-2. Landstuhl cohort. Inadequate fasciotomy risks mortality. Surgeons should have this.
- ² Mubarak SJ, Hargens AR. Compartment Syndromes and Volkmann's Contracture. Saunders, Philadelphia, 1981. First book on compartment syndrome, a dated classic.
- ³ US Army, Medical Research and Materiel Command. Compartment Syndrome: Diagnosis and Surgical Management DVD, 2008. 90 minutes, how to do surgery.
- ⁴ Office of The US Army Surgeon General, Health Policy and Services (HP&S) Directorate, All Army Action Order, Complications after fasciotomy revision and delayed compartment release in combat patients. 15 May 2007. Ritenour message.
- ⁵ Klenerman L. The Tourniquet Manual. London: Springer; 2003. The only book on tourniquets which increase the risk of compartment syndrome somewhat especially if used incorrectly such as a venous tourniquet.
- ⁶ Reis ND. Better OS. Mechanical muscle-crush injury and acute muscle-crush compartment syndrome : with special reference to earthquake casualties. *J Bone Joint Surg Br*. 87(4) :450-3, 2005. Late fasciotomy risks infection and mortality.
- ⁷ Walters TJ, Kragh JF, Kauvar DS, Baer DG. The combined influence of hemorrhage and tourniquet application on the recovery of muscle function in rats. *J Orthop Trauma*. 22(1) :47-51, 2008. Risk factors are interrelated.

Approved by CENTCOM JTTS Director, JTS Director
and Deputy Director and CENTCOM SG

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APPENDIX A
TABLES & FIGURES

Table 1. Risks for Acute Traumatic Compartment Syndrome*	
Decreased Compartment Volume	Tight cast or dressing, closure of prior fasciotomy, excess traction
	External limb compression or crush particularly in obtunded or incapacitated casualty
	Frostbite, burns or electric injury (may include escharotomy)
Increased Compartment Contents	Edema accumulation: embolism, intravascular thrombosis, replantation, venous tourniquet, injections, extravasation, infiltration, ergotamine ingestion Ischemia-reperfusion, swelling, artery injury or spasm, revascularization procedures, prolonged arterial tourniquet use, shock hypoperfusion, angiography and catheterization, limbs positioned well above heart, mal-positioned joints (ankle dorsiflexion,) or stretched muscles
	Prolonged immobilization and limb compression particularly with obtunded or drugged casualty, some surgical positioning
	Hemorrhage, hemophilia, coagulopathy, anticoagulation, vessel injury
	Fractures particularly tibia fractures in adults, supracondylar humerus fractures in children displaced, comminuted, or open fractures increase hemorrhage, swelling, and CS risk
	Popliteal cyst, long leg brace
<i>*Modified from reference 2</i>	

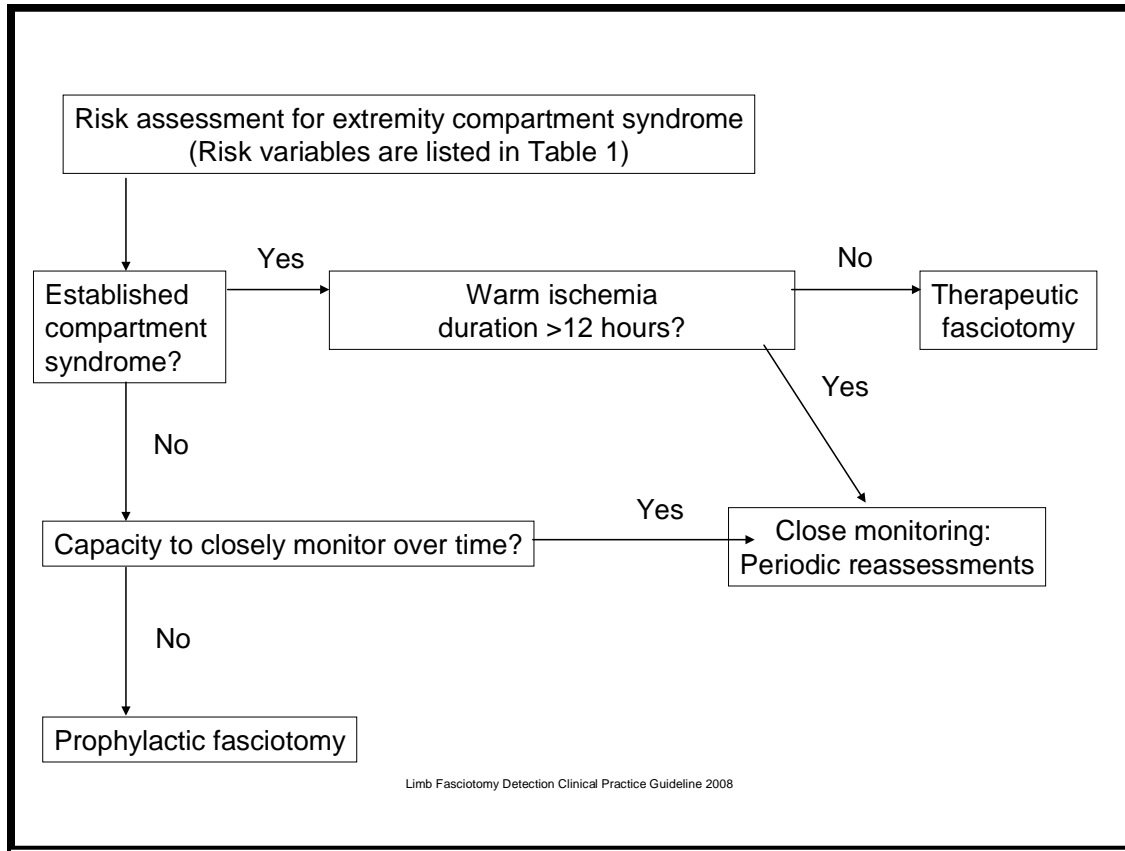


Figure 1.
Algorithm for Clinical Decision Making
on Compartment Syndrome in a Deployed Setting

Table 2. Healthcare Record Data in the Setting of Compartment Syndrome During War.
Was the fasciotomy prophylactic (compartment syndrome absent) or therapeutic (compartment syndrome present)?
When was the fasciotomy indicated and when was the injury? When was the procedure (to determine treatment lag)?
Was the casualty able to be followed closely? If so, what was the clinical course? Was the casualty alert, intubated, or head injured? Was there a nerve injury or nerve block/regional anesthetic?
What was the injury or risk factors, e.g., ischemia-reperfusion, that indicated the procedure?

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Table 2.
Healthcare Record Data in the Setting of
Compartment Syndrome During War.

What are the sources of ischemia-reperfusion in the injury and care of this case?
Associated injuries altering risk of compartment syndrome: shock, occult hypoperfusion, hypoxia, nerve dysfunction, impaired, obtunded, or uncooperative casualty, arterial injury or ischemia, fractures with soft tissue injury, over-resuscitation syndrome, coagulopathies (including hemophilia, etc.), hematoma formation, crush injury, capillary leak syndrome, and prolonged compression.
What were the surgical findings and muscle compartment response to the procedure?
What was the technique (dermotomy, fasciotomy, surgical approach, length of fasciotomy)?
Was there retinaculotomy or epimysiotomy? List names of all compartments released.
What delimited the fasciotomy extent, e.g., anterior leg fascia goes from the proximal tibial crest near Gerdy's tubercle to the anterior ankle extensor retinaculum (crural ligament)?
List associated procedures: debridement, irrigation, fracture fixation, etc.
Planned care: staged? Closure, repeat debridement, delayed primary, skin graft, or flap

Table 3.
Morbidity Risk and Sequelae
of Compartment Syndrome and Fasciotomy

Potential Morbidity: Compartment Syndrome and Early Fasciotomy	skin scar, scaly skin, ulceration, tethered tendons
	postoperative arterial or graft thrombosis, thromboembolic disease
	wound infection, nonhealing fasciotomy wounds
	limb swelling or chronic edema, shape change of limb, muscle hernia
	pain, paresis or paralysis, paresthesia
	coverage challenge: primary closure, delayed primary closure, skin graft, flap

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Table 3.
Morbidity Risk and Sequelae
of Compartment Syndrome and Fasciotomy

	possible repair of arterial injury worsening ischemia-reperfusion injury
Potential Sequelae List: Compartment Syndrome with Late or Incomplete Fasciotomy	mortality, sepsis, multi-organ failure, acute kidney failure,
	myonecrosis, myoglobinemia, myoglobinuria, or rhabdomyolysis
	paresis or paralysis
	stiffness or contracture
	limb amputation, tissue loss, e.g., muscle debridement

Table 4.
Data Sheet: Compartment Names, Main Muscles, and Diagnosis and Procedure Codes

Compartment	Main muscle(s)	Left or Right	Wound Notes, Compartment Syndrome (CS), Diagnoses, Indications, & Findings	Procedure(s) and Tissue Response to Procedure
			958.91: traumatic CS of upper extremity 958.92: traumatic CS of lower extremity 958.99: traumatic CS of other sites 958.90: CS, unspecified Prophylactic (CS absent) or therapeutic (CS present). Artery, vein, clot, & hematoma findings in compartment on exploration	83.12: fasciotomy of hand 83.14: fasciotomy, division of fascia 83.09: incision of fascia 86.09: escharotomy dermatomy, epimysiotomy Response: muscles bulged through fasciotomy, no bulge, pulse returned after absence
Deltoid	deltoid			
Arm, Anterior	biceps, brachialis			

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Table 4. Data Sheet: Compartment Names, Main Muscles, and Diagnosis and Procedure Codes				
Compartment	Main muscle(s)	Left or Right	Wound Notes, Compartment Syndrome (CS), Diagnoses, Indications, & Findings	Procedure(s) and Tissue Response to Procedure
Arm, Posterior	triceps			
Forearm, volar	flexors			
Forearm, dorsal	extensors			
Forearm, mobile wad	brachioradialis			
Hand, interossei	interossei			
Hand, central palmar	flexors			
Hand, hypothenar	digiti minimi			
Hand, thenar	thumb muscles			
Gluteus maximus	gluteus maximus			
Gluteus medius	other glutei			
Tensor fascia lata	tensor			
Thigh, anterior	quadriceps			
Thigh, posterior	hamstrings			
Thigh, adductor	adductors			
Leg, anterior	tibialis anterior			
Leg, lateral	peronei			
Leg, deep posterior	tibialis posterior			
Leg, superficial	gastrocnemius			

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Table 4. Data Sheet: Compartment Names, Main Muscles, and Diagnosis and Procedure Codes				
Compartment	Main muscle(s)	Left or Right	Wound Notes, Compartment Syndrome (CS), Diagnoses, Indications, & Findings	Procedure(s) and Tissue Response to Procedure
posterior				
Foot, interossei	interossei			
Foot, central	flexors			
Foot, lateral	digiti minimi			
Foot, medial	great toe muscles			
Iliacus	iliacus, psoas			

Table 5. Operative Note Template for Dictation, Surgical Planning, or Data Collection	
¹ . Patient	² . Surgeon
³ . Date of Surgery	⁴ . Anesthesia
⁵ . EBL:	⁶ . Tubes
⁷ . Specimens	⁸ . Complications
⁹ . Implants, Devices	
¹⁰ . <u>Indication for operation:</u> established compartment syndrome (therapeutic) risk of compartment syndrome developing (prophylactic)	
¹¹ . <u>Preoperative wound appearance:</u> size (volume of damaged tissue: large surgeon hand ~500ml) depth, location, contamination material or matter	
¹² . <u>Preoperative imaging findings:</u> soft tissue injury seen & fracture	

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Table 5.

Operative Note Template for Dictation, Surgical Planning, or Data Collection

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|--|
| <p>13. <u>Examination under anesthesia, fluoroscopy, and surgical exploration findings:</u></p> <p>distal pulse status</p> <p>wound size, depth, location, contamination, materials or matter; burn eschar location and depth</p> <p>vessel status, pulse, limb perfusion, capillary refill, congestion, edema, color of skin, warmth</p> <p>clot presence, intravascular or extra vascular site, size (volume), location</p> <p>hematoma presence</p> <p>compartment hardness: soft, hard</p> <p>epimysiotomy (if done by muscle name or compartment if known)</p> <p>retinaculotomy (if done by name, e.g., partial proximal ankle extensor)</p> <p>retinaculotomy extended from anterior leg compartment fasciotomy</p> <p>result of fasciotomy and procedure (distal perfusion and pulse; gap in fasciotomy edges on release in cm; bulging out of muscles in compartment)</p> <p>compartments soft or hard</p> <p>muscle color, consistency, contractility, capacity to bleed</p> |
| <p>14. <u>Patient condition, status, disposition and plan:</u></p> |
| <p>15. <u>Key note for air evacuation: "Patient has been monitored for X hours after injury/surgery and has not had progression of signs or symptoms of compartment syndrome."</u></p> |

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